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INTRODUCTION

On August 6, 1988, a leakage of SO_2 occurred on the property of Casco Inc. at Port Colborne, Ontario. Following the discovery of the leakage, SO_2 was vented to the atmosphere to reduce the pressure in the tank. As a consequence of the action, the nearby vicinity of the Casco operation was subjected to a fumigation of SO_2. Subsequently, injury to vegetation in the affected area was reported. This report includes information obtained in investigations conducted in 1989.

INVESTIGATIONS

A sample of injured foliage from a cedar (*Thuja occidentalis*) tree growing near the Casco operation was submitted to the Phytotoxicology Laboratory on December 14, 1988. The delay in delivery of the sample had resulted in spoilage which made accurate diagnosis impossible. The injury observed, however, was not inconsistent with that caused by SO2. Due to the lateness of the season, no field investigations were conducted at that time.

In response to a request from the Welland District Office, Ontario Ministry of the Environment to the Phytotoxicology Section, Air Resources Branch, a surveillance program was set up to determine the extent of damage to vegetation. Two site visits were carried out during 1989 to document the presence of injury and to collect foliage samples for chemical analysis.

The first site visit took place on May 24, 1989. At 16 sites, inspections were made of the vegetation present at each location. The sites were mainly along Colborne Street but also along road accessible routes in the vicinity of Casco.

Foliage samples were collected at 5 locations selected along the old canal running north-south to the west of the Casco property. At each site, foliage samples were collected in triplicate from cedar trees which were the predominant conifer in the area. Foliage was not collected from hardwoods because 1) the foliage had only recently emerged from the buds and 2) only conifer foliage from 1988 had been exposed to the SO_2 spill.

On September 7, 1989, the vegetation sampling sites were again visited. Foliage was collected in triplicate from the same cedar trees as were sampled in May. In addition, single samples of foliage were collected from American elm (*Ulmus americana*), white ash (*Fraxinus americana*), silver maple (*Acer saccharinum*) and Carolina poplar (*Populus deltoides*) depending upon availability at each site.

INJURY TO VEGETATION

At the time of the first visit on May 24, 1989, no injury was noted on hardwood foliage, primarily because the foliage was so young. A small amount of dieback of small tree branches was noted on some trees was noted but was considered to be entirely normal. Injury to the tips of shoots of cedar were common at all sample sites but the tree nearest to Casco showed the greatest amount of injury. This information is presented in Table I and Figure 1.

Table I.

Observations of condition of foliage on white cedar trees growing in the vicinity of Casco Inc. Port Colborne, Ontario, May 24, 1989.

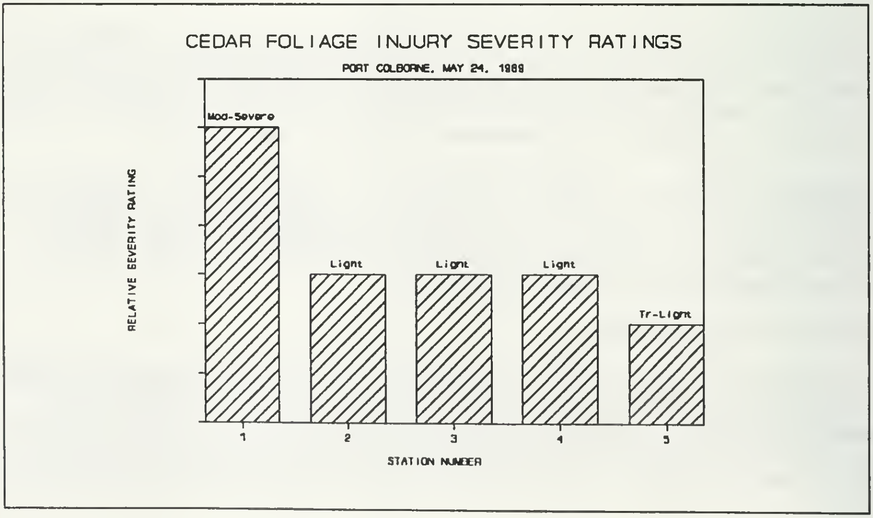
Location	Foliage Condition.
Site 1	- moderate to severe terminal necrosis of foliage - thin coating of greyish powdery material on foliage
Site 2	- light terminal necrosis
Site 3	- light terminal necrosis
Site 4	- light terminal necrosis
Site 5	- trace - light terminal necrosis

Legend for Table I.

Trace = >0 - 1%
Light = 2 - 10%
Moderate = 11 - 35%
Severe = >35%

* - trees at all sites had a light compliment of leaf mining insect (*Argyresthia thuiella*) injury and old cones were common

Figure 1



At the time of the visit on September 7, 1989, there was no visible injury to any hardwood species that might be attributed to SO_2. There were a variety of insect feeding injuries and foliar diseases but these were considered entirely normal in view of the onset of fall senescence. White cedar still showed a residual damage previously observed but fresh (1989) growth was present. At sample Sites 1 and 2, a white dusty deposit was noted on the foliage.

SAMPLE PREPARATION

All samples were processed separately in the Phytotoxicology Laboratory then submitted to the Laboratory Services Branch, Ontario Ministry of the Environment for analysis. The vegetation samples were oven-dried, ground in a Wiley mill and stored in glass bottles. The chemical analyses performed were sulphur, chloride and potassium determinations.

CHEMICAL ANALYSIS RESULTS

The results of the chemical analysis are shown in Tables 1 to 3. There were variable concentrations of sulphur, chloride and potassium measured in the hardwood foliage collected in September 1989. Natural differences in concentration with respect to species were noted (ie. Poplar> ash> maple> elm in the case of sulphur content). No pattern of contamination with consideration of distance from the Casco operation was detected.

In the case of the cedar foliage samples, there was a clear indication of elevated sulphur at Site 1 in both spring and fall collections. The degree of elevation in the fall collection was less pronounced. The lower fall concentrations can be attributed to several possible factors including leaching of sulphur, translocation to other parts of the tree, sloughing of necrotic (contaminated) tissues and/or dilution by new foliage produced in 1989. Chloride and potassium in the cedar foliage did not demonstrate any distribution pattern that could be related to the Casco operation.

Statistical tests were performed on the chemical analysis data for the cedar foliage. These are summarized in Table II. These confirm that sulphur values at Site 1 were very highly significantly greater than at the other sites. The difference between spring and fall sulphur concentrations were statistically significant. Significant differences in content of chloride and potassium were noted among stations but no pattern relative the Casco plant was obvious. Significantly different fall:spring concentrations in the cedar foliage are attributed to natural physiological changes in the foliage.

SULPHUR DIOXIDE INJURY TO PLANTS

The relationship between sulphur dioxide concentration/duration of a fumigation and the subsequent development of acute injury is well known. Based on field observations for Ontario, Dreisinger (1) derived the following conditions under which SO_2 could cause vegetation injury (Figure 2):

0.95 ppm SO_2 for 1 hour
0.55 ppm SO_2 for 2 hours
0.35 ppm SO_2 for 4 hours
0.25 ppm SO_2 for 8 hours

Table II.

Statistical summary of chemical analysis data for white cedar foliage collected in the vicinity of Casco Ltd, Port Colborne, Ontario, 1989

Element	Effect of Site			Effect of Season		
	F-value	Significance	Pattern	F-value	Significance	Pattern
Sulphur	23.73	***	1 5 3 2 4	6.16	*	Spr.>Fall
Chloride	5.03	**	1 5 4 3 2	0.95	NS	
Potassium	7.68	***	3 1 5 2 4	134.84	***	Fall>Spr.

Data were normalized by log transformation

If any of these conditions were met in the daylight hours, then the fumigation intensity was assigned a value of 100 for convenience. If the fumigation intensity is 100 or over, then the fumigation is termed a potentially injurious fumigation (PIF). A PIF does not always result in injury since other factors such as species sensitivity, growing season and environmental factors also have some bearing on susceptibility to injury.

In the case of the SO_2 spill at Casco, there are no ambient air measurements upon which to base injury/dose relationships. In this report, the estimated concentrations of SO2 predicted from modelling data were used. A comparison of the predicted SO_2 concentrations over a period of 3 hours (8 am to 11 am) on the day of the spill with the dose required to cause acute injury to vegetation show that the ambient concentrations were grossly in excess of that required to cause injury. Even at 300 metres, the dose would be about 15 times higher than that required to cause injury (Table III).

As noted above, a number of factors control the susceptibility of a plant to SO_2 injury. Normally, cedar is regarded as being moderately tolerant to SO_2. Also, the lateness of the season would confer an added degree of tolerance which is lacking in succulent foliage. Despite this, the vegetation in the area would not be able to tolerate the levels of SO_2 encountered during the spill episode and severe injury to plants (especially those less tolerant than cedar) would be expected.

CONCLUSIONS

Based on the observations of injury to cedar foliage, foliage sulphur content and modelled dispersal of the SO_2 gas, it can be concluded that the SO_2 spill at Casco in August, 1988, was responsible for injury to vegetation in the vicinity of the operation.

LITERATURE CITED

Dreisinger, B.R. 1970. Monitoring atmospheric sulphur dioxide and correlating its effects on crops and forests in the Sudbury area. In: Proc. Conference on Impacts of Air Pollution, Toronto. 23 pp.

Table III.

Comparison of modelled SO_2 concentrations and Potentially Injurious Fumigations based on 3- hour fumigation (8 am to 11 am)

Distance m	Modelled Concentration mg/m^3	ppm	Excess* Factor
30	130	50	119
60	100	38	90
90	70	27	64
150	42	16	38
200	30	11	21
300	17	6.5	15

* Excess factor calculated as ratio between modelled SO_2 concentration and dose required to cause acute SO_2 injury.

Figure 2

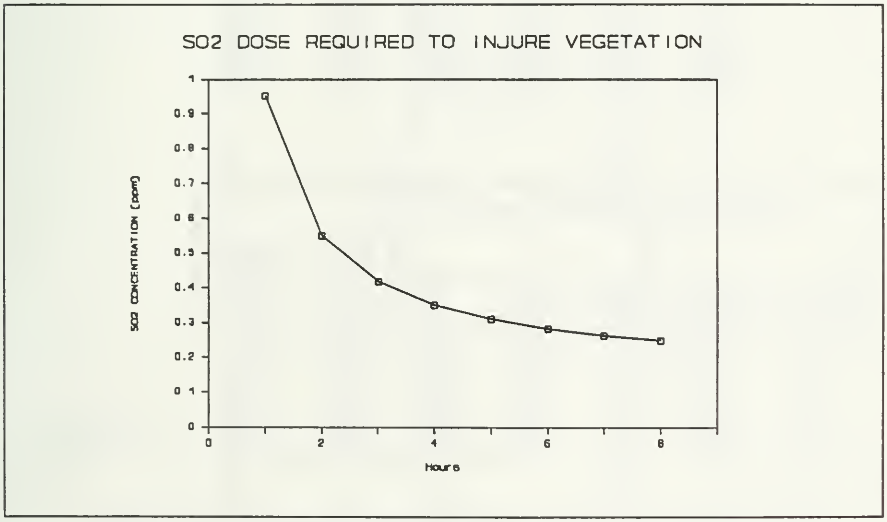


Table IV. Sulphur content of tree foliage collected in the vicinity of Casco, Port Colborne, Ontario, 1989**

Station Number	Carolina Poplar	Silver Maple	American Elm	White Ash	Fall White Cedar	Spring White Cedar
1.	0.530	0.160	0.160	0.240	0.110	0.163
2.	0.720	0.150	0.096	0.310	0.077	0.080
3.	-.---	0.120	0.058	0.280	0.076	0.089
4.	0.700	0.230	0.150	0.190	0.080	0.075
5.	0.530	0.190	0.150	0.260	0.083	0.083

Table V. Chloride content of tree foliage collected in the vicinity of Casco, Port Colborne, Ontario, 1989**

Station Number	Carolina Poplar	Silver Maple	American Elm	White Ash	Fall White Cedar	Spring White Cedar
1.	0.056	0.110	0.140	0.052	0.087	0.101
2.	0.086	0.044	0.098	0.050	0.045	0.045
3.	-.---	0.028	0.036	0.026	0.076	0.047
4.	0.062	0.210	0.088	0.074	0.049	0.121
5.	0.050	0.010	0.110	0.044	0.083	0.091

Table VI. Potassium content of tree foliage collected in the vicinity of Casco, Port Colborne, Ontario, 1989**

Station Number	Carolina Poplar	Silver Maple	American Elm	White Ash	Fall White Cedar	Spring White Cedar
1.	1.50	1.20	0.85	0.91	0.68	0.48
2.	1.10	0.81	1.00	0.81	0.59	0.42
3.	-.---	1.00	1.30	1.00	0.70	0.50
4.	1.80	0.46	0.97	1.20	0.55	0.44
5.	1.70	1.00	1.10	1.10	0.60	0.41

Legend for Tables IV - VI

All data are expressed on % dry weight basis

* = Values reported are for single samples except for White Cedar which are averages of samples collected in triplicate.

** = All collections made on September 7, 1989 except Spring White Cedar which was collected on May 24, 1989.

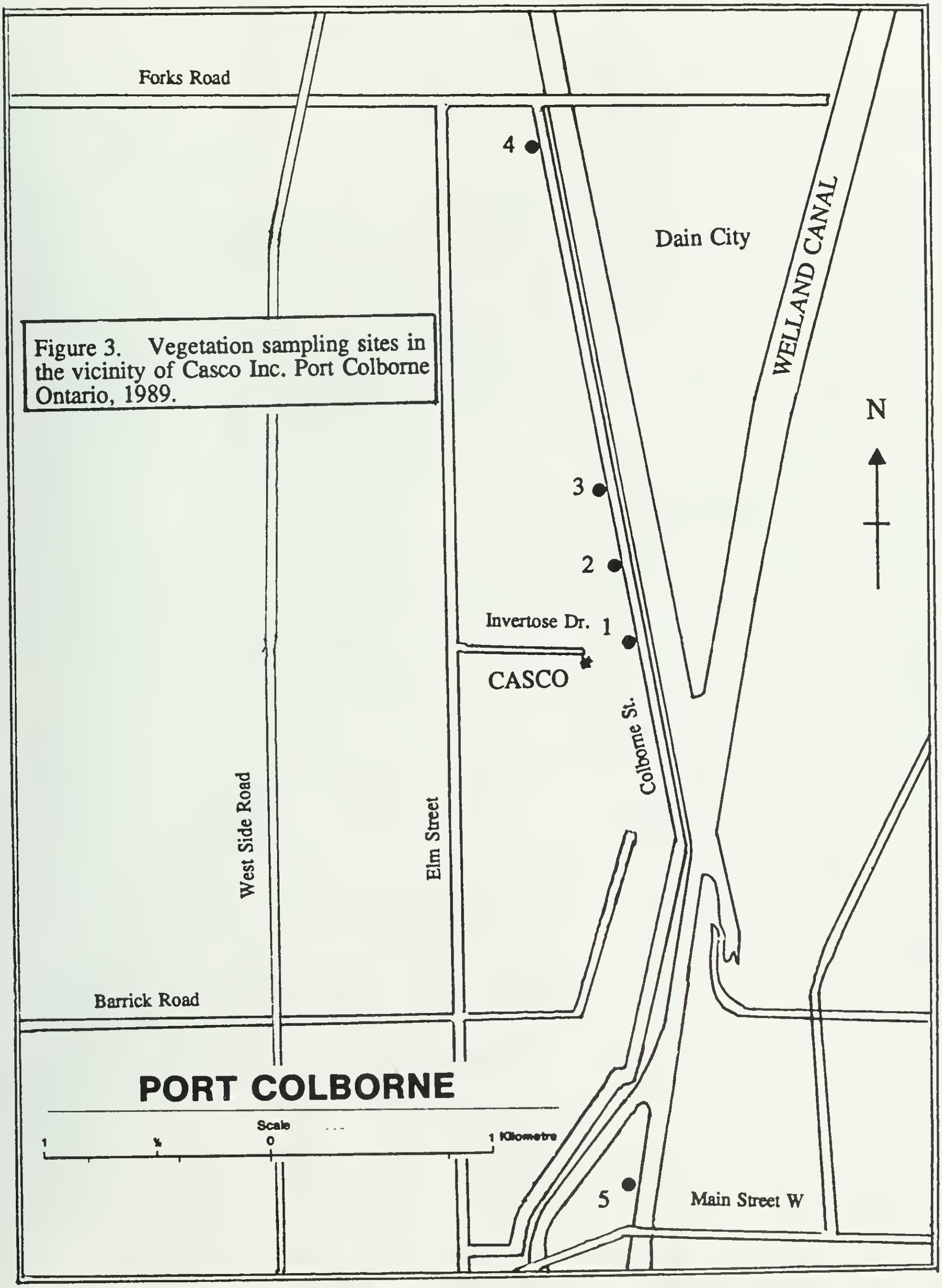


Figure 3. Vegetation sampling sites in the vicinity of Casco Inc. Port Colborne Ontario, 1989.